THE CONSTRUCTION OF PLYWOOD SHIPPING CONTAINERS

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CONSTRUCTION
OF PLYWOOD
SHIPPING CONTAINERS

FOREWORD

It is generally recognized that Douglas fir plywood possesses characteristics that make it a superior material for boxing and crating. Plywood boxes are strong, lightweight, dust-proof, easy to assemble, resistant to diagonal wracking, able to absorb punishment and difficult to pilfer. They have a high percentage of usable volume, are often capable of multiple use and are unlikely to allow damage to their contents by distortion under rough handling.

Plywood boxes are economical; with current shipping conjestion their reduced weight and volume is an obvious advantage, particularly for air express and certain overseas shipments. In cross-country freight shipments the reduced shipping charges on the lower-weight plywood boxes will generally more than equalize the lower material cost of lumber construction. Lower fabrication costs, including less waste material, and reduced losses and damage claims for the plywood container would show additional direct savings.

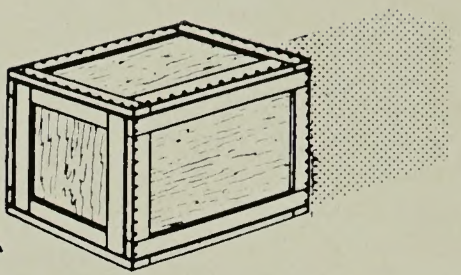
A few actual performance comparisons between lumber and plywood boxes made and tested in the Research Laboratory of the Douglas Fir Plywood Association may serve to illustrate the advantages of using Douglas fir plywood. The results given in the following text, while applying rigorously only to the specific boxes tested, are considered to be representative.

However, it should be borne in mind that these tests are by no means exhaustive, in that the design of every type of box is an individual problem because of the large number of variables involved. For the guidance of the designer who is interested in providing a box to solve a particular shipping problem, some basic principles have been stated by the United States Forest Products Laboratory as the result of elaborate tests made there on many types of containers. These principles are presented in the U. S. D. A. Technical Bulletin No. 171, "Principles of Box and Crate Construction." Additional information is contained in a pamphlet published by the American Management Association, 330 West 42nd Street, New York, entitled "Packaging War Material For Overseas Shipment."

CLEATS FOR PLYWOOD BOX CONSTRUCTION

Cleated plywood boxes are well suited for shipment of fragile articles that might be damaged by even a slight amount of wracking or distortion of the container. This stability results from the rigidity afforded by one-piece faces and from the high resistance of plywood to splitting and to shearing or tearing away from fastenings.

The cleats of the box provide a means of fastening the panels together, prevent crushing due to loads concentrated at corners and edges, and add rigidity against distortion under rough handling and superimposed loads. The width and thickness of the cleats depend upon the type and weight of contents in a particular box design. The thickness of plywood required varies with the style of the box and to a certain extent with the type and weight of contents. Generally, single-cleated boxes require thicker plywood than do full-cleated boxes because of the tendency of stresses to concentrate at the point of nailing.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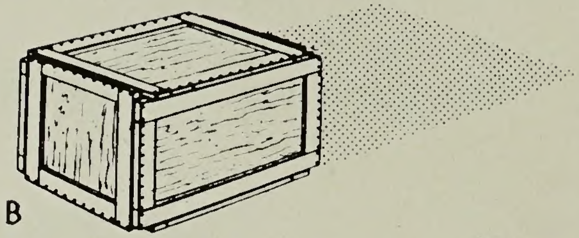
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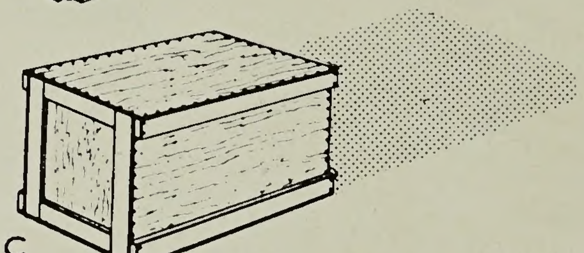
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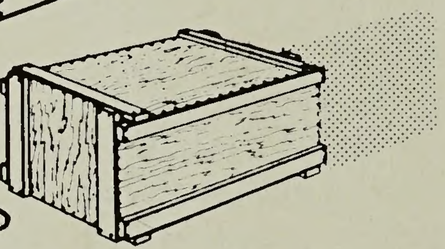
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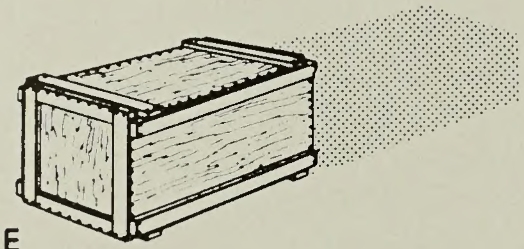
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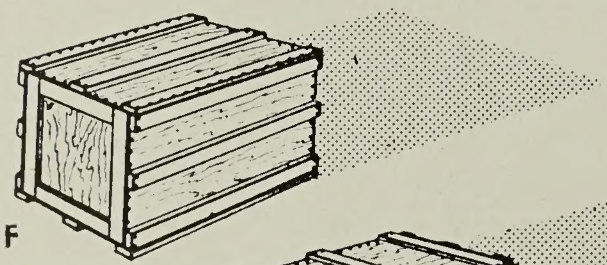
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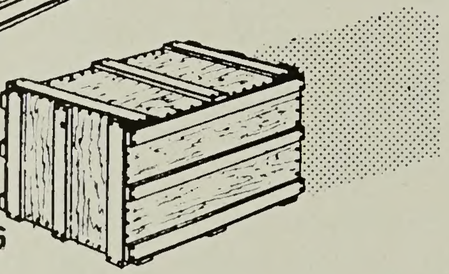
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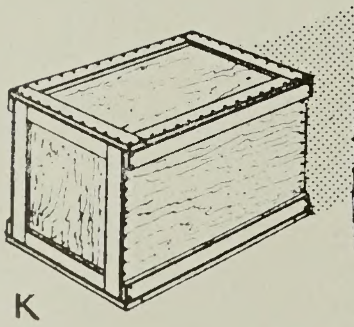
The development of the full strength and rigidity of these containers depends upon proper assembly. Large-headed nails or staples must be used and every nail or staple must pass through the plywood and cleat and be clinched. In practically all such containers, nailing is the most important feature in developing and maintaining high strength. For maximum rigidity and where water-tight boxes are desired the plywood should be glued to the cleats with a synthetic resin adhesive, using sufficient nails to hold the surfaces in contact until the glue sets.

Illustrated on this page are some of the styles of cleated plywood boxes which have been adopted as standard by the Plywood Box Manufacturer's Association of America. Of these only styles A and B with two nailing cleats on each edge are acceptable for overseas shipment of war materials. Styles A, B, and D are those most commonly used. Styles A and B have four cleats on each face of the box and are often called full-cleated panel boxes. Styles B, D, E, and G have 3-way-corner construction.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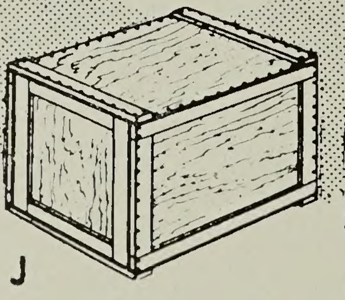
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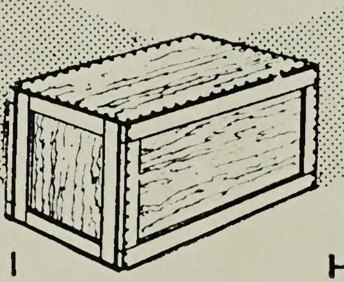
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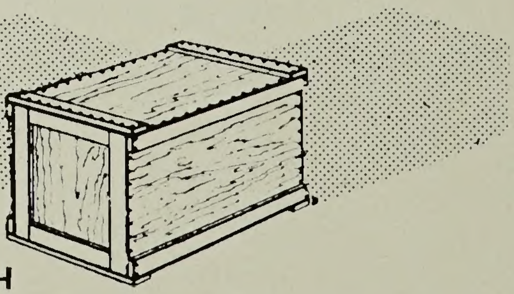
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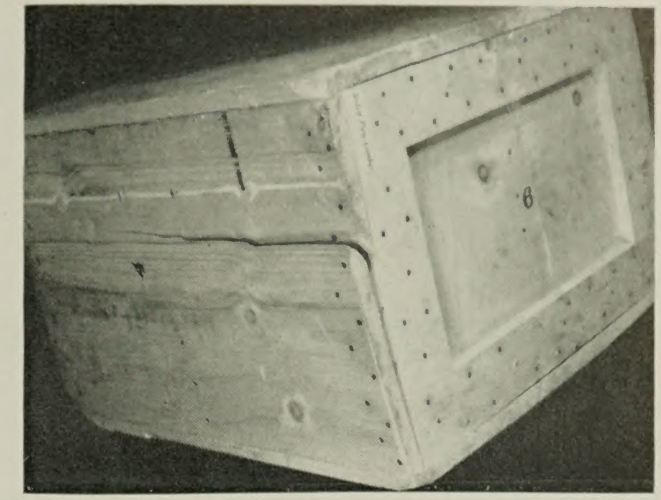
DROP TEST

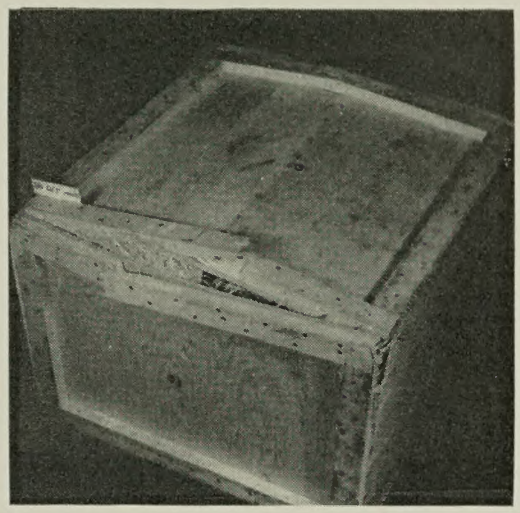
One laboratory test considered shipping containers for 160-ounce battery acid bottles and tank batteries. The boxes carrying filled bottles packed in excelsior were dropped from gradually increasing heights, the impact being taken on each edge and corner in succession.

Results of tests on boxes designed to hold four bottles are graphically shown in Figure 1, together with pictures of the boxes after the tests. Full-cleated nailed and glued boxes of 5/16" thick plywood best withstands the abuse. Next best structurally was the plywood box of similar panel thickness nailed without glue, which failed principally at the cleats. The nailed lumber box, of the type already in use, failed more completely with less abuse. (For further data on the relative strength of nailing or gluing of plywood boxes, see pages 8 and 9, dealing with results of Exposure tests.)

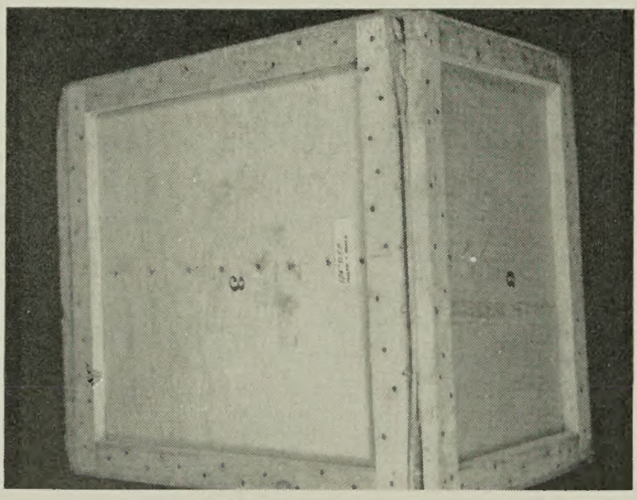
In addition to being more sturdy, the empty plywood boxes averaged 50% less weight and occupied 12½% less space than the lumber containers. Photographs of some of the boxes after the test are shown on this page.



Four-bottle capacity box made of ¾" lumber, nailed only.

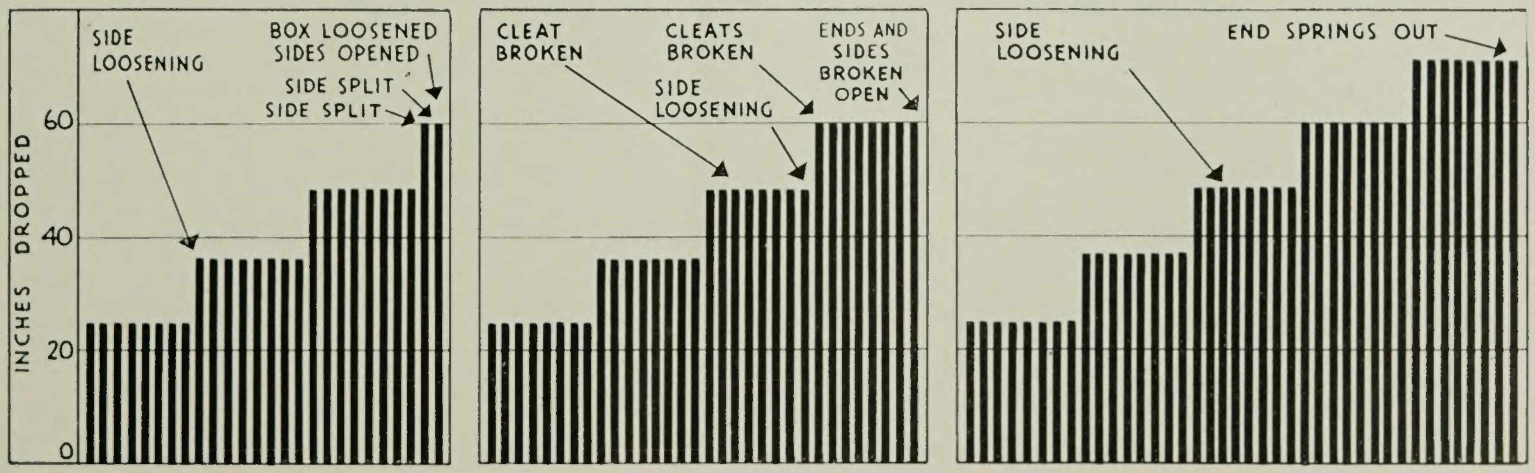


Four-bottle capacity box made of 5/16" plywood, nailed only.



Four-bottle capacity box made of 5/16" plywood, nailed and glued.

Figure 1. Graphs illustrating results of tests on four-bottle capacity boxes shown to the right.

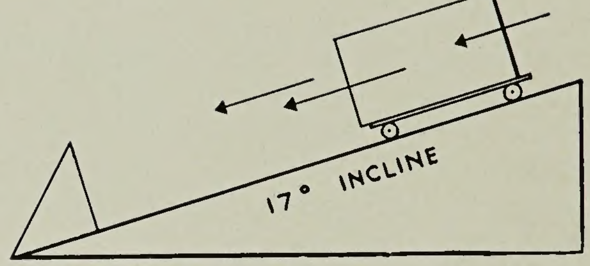


Lumber—Nailed Only.

Plywood—Nailed Only.

Plywood—Nailed and Glued.

INCLINE TEST



Method Used in Incline Tests.

Another method of testing was employed for comparing shipping containers for truck motors and truck motor parts. In this case, a 17 degree incline was used because the gross weights of the loaded boxes ranged from 180 lbs. to 825 lbs. The boxes were placed on a dolly and allowed to roll freely down the incline for a distance of one to twelve feet and to strike against a bumper at the lower end. The boxes, fully loaded with sand bags in special interior crates, were allowed to strike against one end and then against one edge in succession until advanced failure was reached.

The boxes were all constructed as recommended in U.S.D.A. Technical Bulletin 171, except 6d nails were used in the lumber boxes because the 7d nails specified were unavailable. As in the previous tests, the ¾" fir lumber boxes weighed from one-sixth to one-half more than the ⅜" plywood boxes.

The graphs and pictures of two box types tested show the heavier punishment absorbed by the plywood boxes and the fact that no serious damage was done to them, whereas the lumber boxes tended to split and fall part under appreciably less abuse. Similar results were obtained with the third type of box. The strength of the plywood boxes was largely due to the single-piece side construction.

Table 1

CONSTRUCTION DETAILS OF INCLINE TEST BOXES

BOX NO.	CONSTRUCTION	WEIGHT	
		Empty	Loaded
Type 2-A 61¾"x38⅝"x22⅝" Figure 2.	⅜" plywood, top, bottom, sides and end. Full cleated with 13/16" x 2⅜" cleats, having three-way corners. Nailed with 10d cement-coated box nails at 3" spacing.	93#	473#
Type 2-B Figure 3.	¾" shiplap top, bottom, sides and ends. End cleats ¾" x 2⅝". Nailed with 6d cement-coated box nails spaced at 2" spacing.	129#	509#
Type 3-A 41¾"x22¾"x38¾" Figure 4.	⅜" plywood top, bottom, sides and ends. Full cleated with 1-1/16" x 2⅝" cleats, having three-way corners. Nailed with 10d cement-coated box nails at 2" spacing.	96#	836#
Type 3-B Figure 5.	¾" shiplap top, bottom, sides and ends. End cleats ¾" x 2⅝". Nailed with 6d cement-coated box nails spaced at 2" spacing.	112#	852#

NUMBER AND LENGTH OF RUN ON INCLINED PLANE FOR TWO TYPES OF BOXES

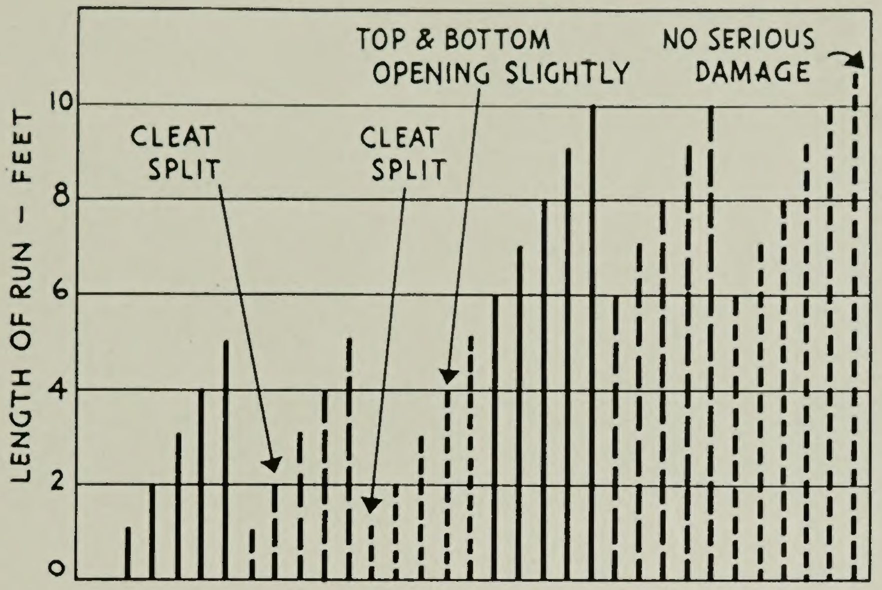


Figure 2. Plywood Box Type 2-A

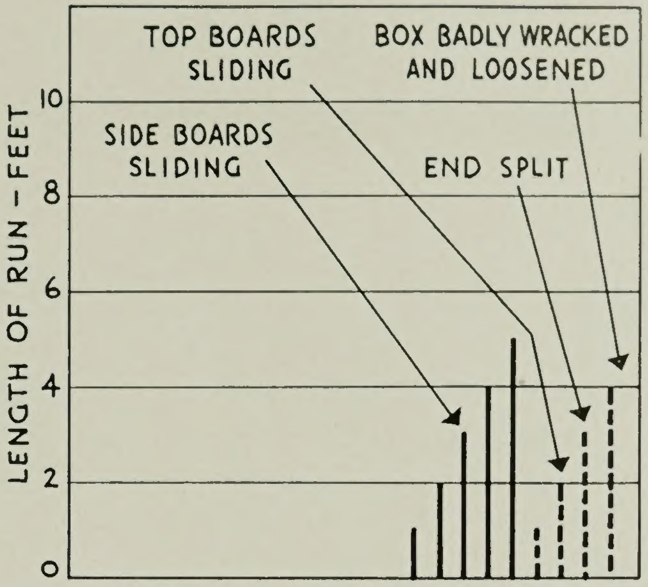


Figure 3. Lumber Box Type 2-B

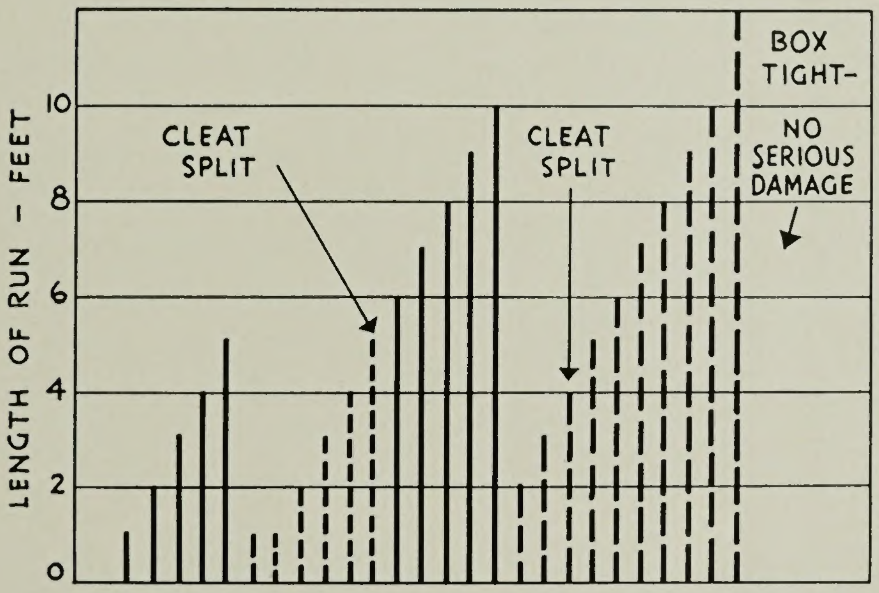


Figure 4. Plywood Box Type 3-A

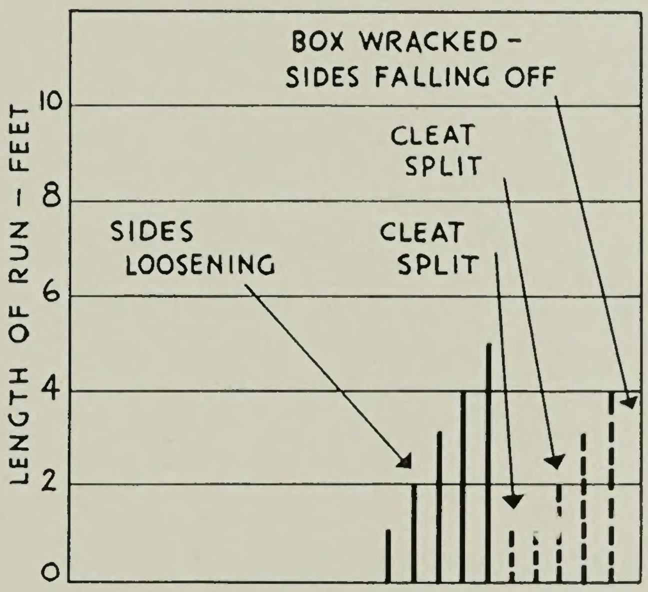
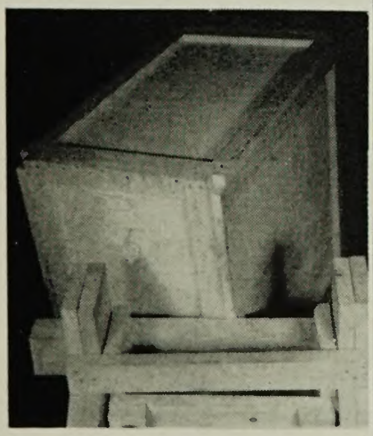
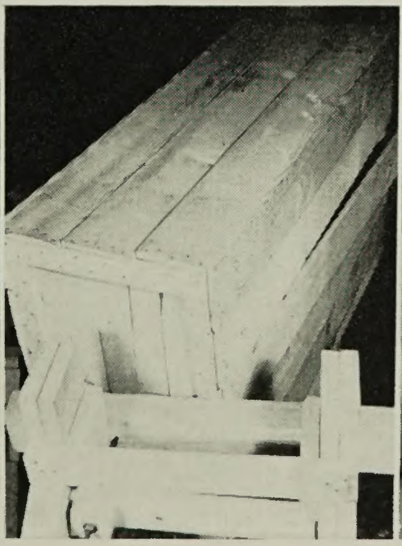


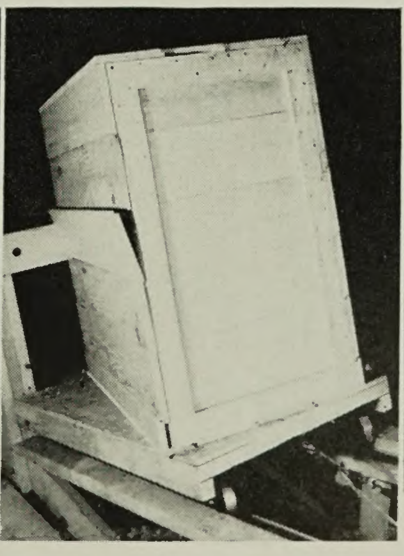
Figure 5. Lumber Box Type 3-B



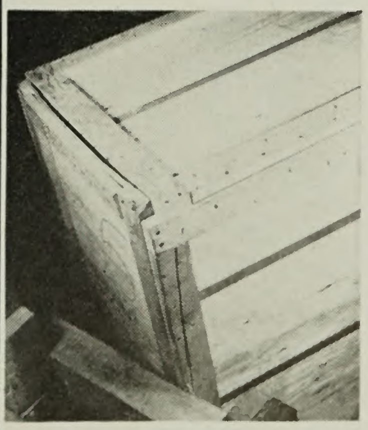
Plywood box Type 3A after test. (See Fig. 4.)



Lumber box Type 2B after failure. (See Fig. 3.)

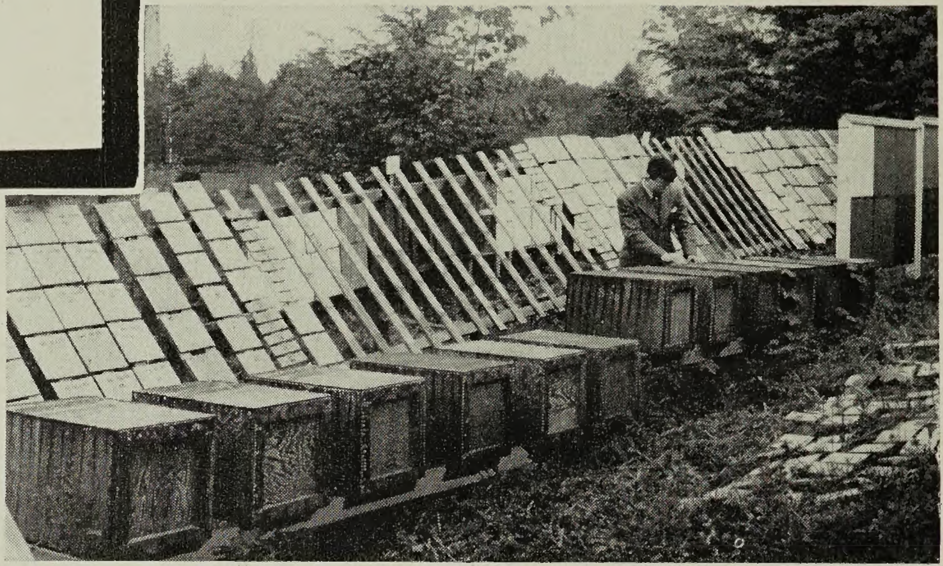


Lumber box Type 3B after failure. (See Fig. 5.)



Plywood box Type 2A after test. (See Fig. 2.)

EXPOSURE TESTS



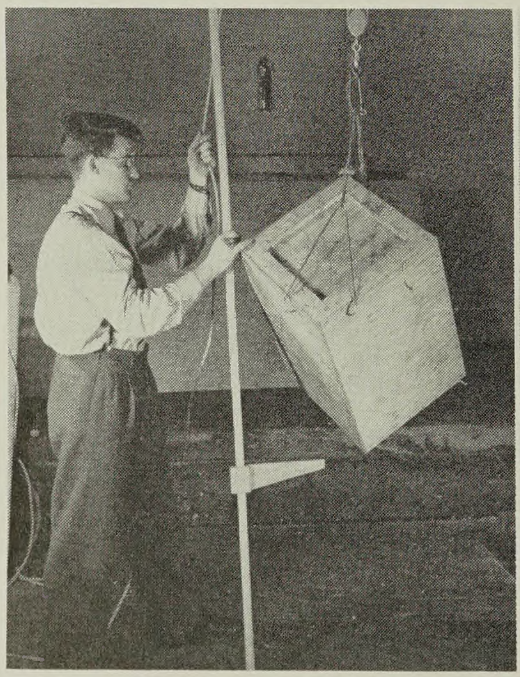
Boxes on exposure fence after nine months in the weather.

The drop-cornerwise test was adopted for the testing of a dozen cleated plywood boxes which had been exposed to the Puget Sound weather for nine months, starting September 2, 1942. Four of the boxes in this group were fabricated with moisture resistant plywood, four with PLYFORM and four with EXTERIOR type of ¼" and 5/16" thicknesses. Three of the moisture resistant type boxes were nailed only, while the other nine boxes were nailed and glued with a cold setting resin glue.

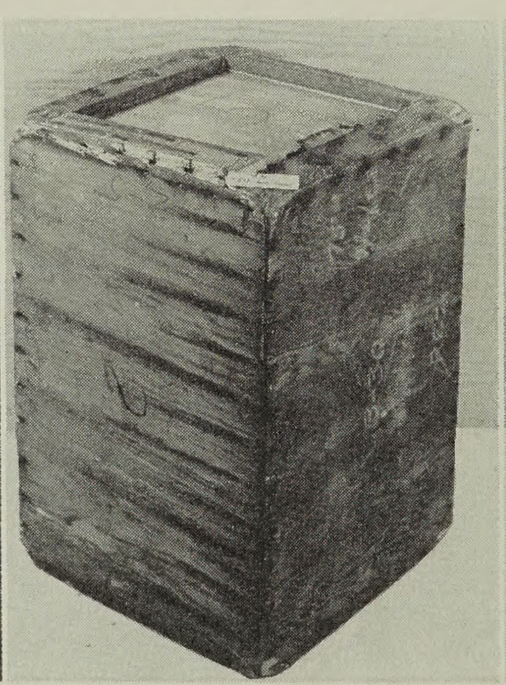
These boxes were loaded with plywood scraps and in addition, each box carried small sacks of staple foods (flour, starch and salt) in the bottom corners, bringing the average box weight up to 70 lbs. The foods were undamaged after the long exposure in the glued boxes; those in the nailed boxes evidenced a pronounced musty odor.

In the drop-cornerwise test, drops were made on the corners in numerical rotation starting at a height of 48". After the box had been dropped on each of the eight corners, the height of the drop was increased 12" and the cycle repeated until complete failure occurred, when the box opened up.

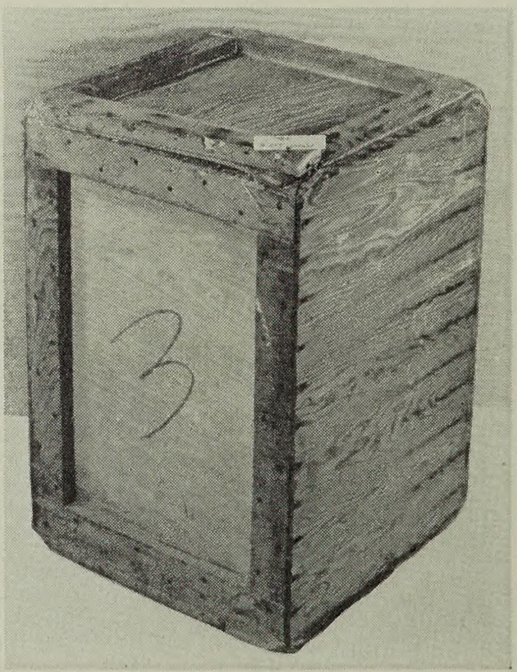
An additional exposure test was made by float-



General set-up and equipment used in drop test.



Specimen B-30, which was treated with resin sealer, after the test.



Specimen B-31 after test. Failure occurred in glue joint.

ing three boxes in sea water for two weeks. They were of the same construction as the previous set, and loaded in the same manner. To provide a basis for estimating the effect of weathering, eight more boxes were built and tested without weathering.

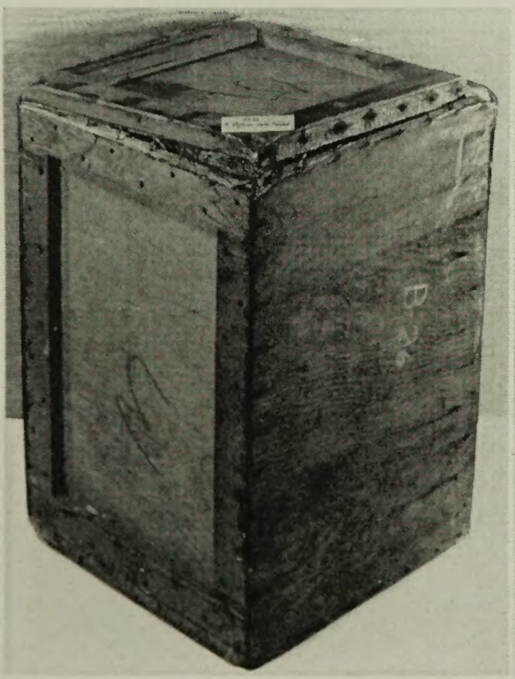
Results of the tests are shown in Table 2. The total amount of energy absorbed indicates the amount of abuse taken by each box.

Examination of the Table reveals that it is possible to build a plywood box moisture-tight for short-time immersion or long-time atmospheric exposure if sanded plywood and glued joints are used. Furthermore, it is interesting to note that of the boxes which had been exposed for several months, those which were nailed only took more abuse than those which were nailed and glued. Also, no decrease in shock-resisting ability results from exposure to the elements.

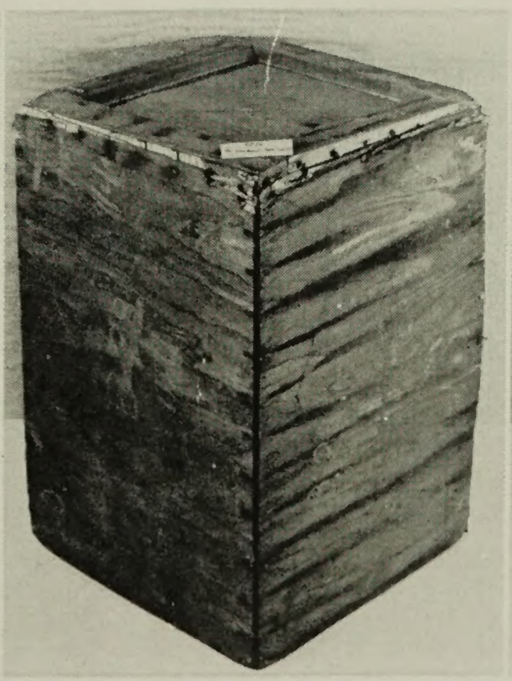
Table 2. RESULTS OF EXPOSURE TEST

	CONSTRUCTION			WEIGHT, LBS.			Av. Moist.	Total Ft.	
BOX NO.	Plywood Type and Thickness	Joints	Treatment	Original	At Test	% Increase	Cont. at Test	Lbs. En'gy Absorbed	REMARKS
			BOXES EXPOSED NINE MONTHS TO WEATHER						
20	5/16" M-RES.	Nailed Only	None	60	70	17%	22%	7,140*	Badly delam. Contents damp
21	"	"	Resin Sealer	65	73	12%	21%	7,884	Badly delam. Contents damp
22	"	"	None	61	70	15%	18%	10,850	Badly delam. Contents damp
23	"	Nailed & Glued	Resin Sealer	69	74	7%	15%	7,103	Badly delam. Cont. fairly dry
24	1/4" PLYFORM	"	Resin Sealer	68	70	3%	13%	2,590	Slightly delam. Contents dry
25	"	"	None	72	75	4%	14%	4,650	Slightly delam. Contents dry
26	"	"	Resin Sealer	75	79	5%	13%	4,503	Slightly delam. Contents dry
27	"	"	None	68	70	3%	13%	4,340	Slightly delam. Contents dry
28	5/16" EXT.	"	Resin Sealer	74	90	18%	16%	7,020	No delam. Contents wet
29	"	"	None	77	86	12%	15%	4,472	No delam. Contents dry
30	1/4" EXT.	"	Resin Sealer	75	76	1%	10%	6,840	No delam. Contents dry
31	"	"	None	76	80	5%	11%	4,560	No delam. Contents dry
			CONTROL BOXES—NOT EXPOSED TO WEATHER						
32	1/4" M-RES.	Nailed Only	None	80	80	0	9%	1,600	
33	"	"	"	80	80	0	9%	2,240	
34	"	Nailed & Glued	"	80	80	0	9%	3,760	
35	"	"	"	80	80	0	9%	5,360	
36	5/16" M-RES.	Nailed Only	"	80	80	0	9%	6,240	
37	"	"	"	80	80	0	9%	4,960	
38	"	Nailed & Glued	"	80	80	0	9%	6,240	
39	"	"	"	80	80	0	9%	6,240	
			BOXES FLOATED IN SALT WATER FOR TWO WEEKS						
40	1/4" PLYFORM	Nailed & Glued	None	76	81	7%	TestWet	3,402	No water penetrated box
41	5/16" M-RES.	"	"	64	83	30%	"	4,721	Free water in box
42	5/16" EXT.	"	"	57	72	26%	"	9,144	Free water in box

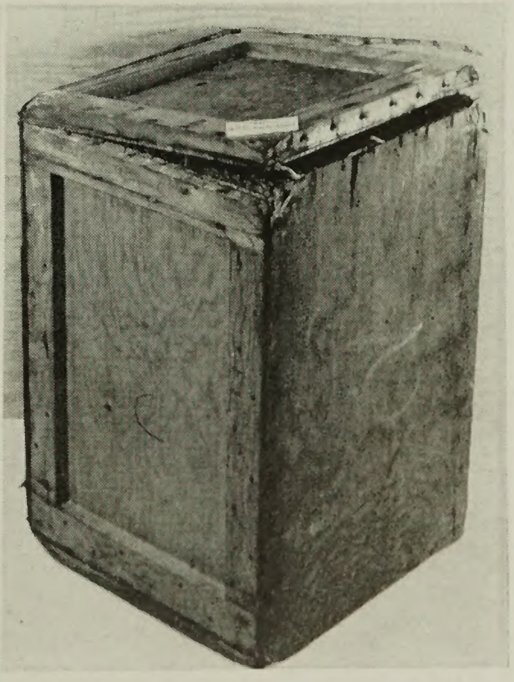
*This box took an additional 7,560 Ft.-Lbs. in drops from 12" to 42".



Specimen B-26 after test. Plywood used here is highly moisture-resistant, but not waterproof.



Specimen B-28 after test. Contents were kept dry during exposure.



Specimen B-22 after test. Note lateral bearing failure of nails in plywood.

DIAGONAL CRUSHING TEST

Another type of box tested was the relatively small ammunition box having external dimensions of 10″ x 10″ x 16″. This size was chosen to facilitate testing, although the same type of box is used in larger sizes. In view of the vast quantities of these boxes which are shipped abroad, the principal objective of the test was to find the box which occupied the least volume, in order to conserve war-vital cargo space, while at the same time retaining adequate strength.

In this series of tests the strength value is the maximum load than can be withstood in crushing along diagonally opposite corners, a standard type of test illustrated on page 11. While it is difficult to say what is the minimum strength value required in a box of this kind, nevertheless it is possible to make comparisons with familiar types of boxes of proven serviceability, such as boxes 1 and 2 in Table 3 at bottom of this page.

An inspection of the Table reveals the beneficial effect of using plywood for the top and bottom of the box. For example, comparison of Box 1 and Box 4 shows that while they have the same strength, the box with ¼″ plywood top and bottom requires 10% less volume than the all lumber box, based on equal inside dimensions of 8½″ x 8½″ x 14½″. Comparison of Boxes 2 and 3 with 5 and 6 respectively, indicates that the boxes with 5/16″ plywood tops and bottoms are 24% stronger and occupy 9% less volume than the all lumber boxes. The boxes using

Table 3. **RESULTS OF DIAGONAL CRUSHING TESTS ON AMMUNITION BOXES**

BOX NO.	SIDES	TOP & BOTTOM	ENDS	VERTICAL JOINTS	Percent[1] Usable Vol.	Ultimate Load, Lbs.	FAILURE
1.	¾″ Pine[2]	¾″ Pine	¾″ Pine	Notched and double nailed[4] with 5d box.	65.5%	3070	Lumber sides split.
2.	¾″ Fir[3]	¾″ Fir	¾″ Fir	Notched and double nailed with 6d cement-coated.	65.5%	2860	Lumber top split.
3.	¾″ Fir	¾″ Fir	¾″ Fir	Notched, double nailed[5] and glued.	65.5%	3930	Lumber top split.
4.	¾″ Pine	¼″ Plywood	¾″ Pine	Same as Box No. 1	73.1%	3020	Top and bottom nails failed laterally.
5.	¾″ Fir	5/16″ Plywood	¾″ Fir	Same as Box No. 2	72.2%	3570	Lumber side and ends split.
6.	¾″ Fir	5/16″ Plywood	¾″ Fir	Same as Box No. 3	72.2%	4860	Ends split. Nails in top overturned.
7.	¾″ Fir	⅜″ Plywood	¾″ Fir	Same as Box No. 2	71.2%	3940	Top and bottom nails failed laterally.
8.	¾″ Fir	⅜″ Plywood	¾″ Fir	Same as Box No. 3	71.2%	4880	Joints between sides and edges failed.

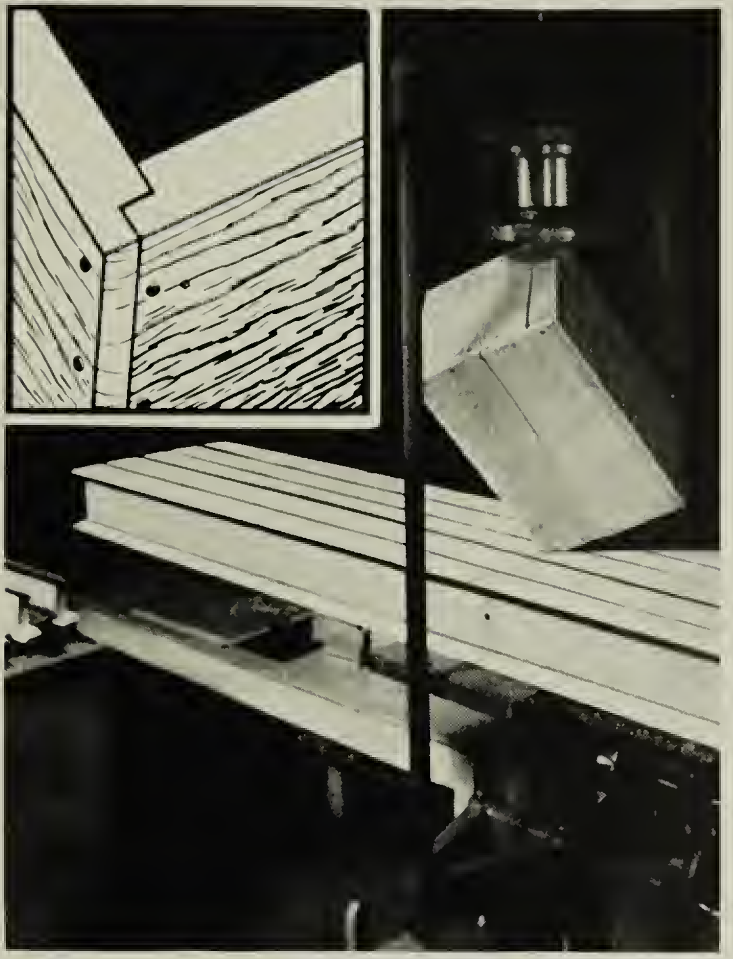
[1] Internal volume in percentage of external volume.

[2] Western white pine.

[3] Douglas fir.

[4] Type of joint shown in picture on page 11.

[5] Top not glued.

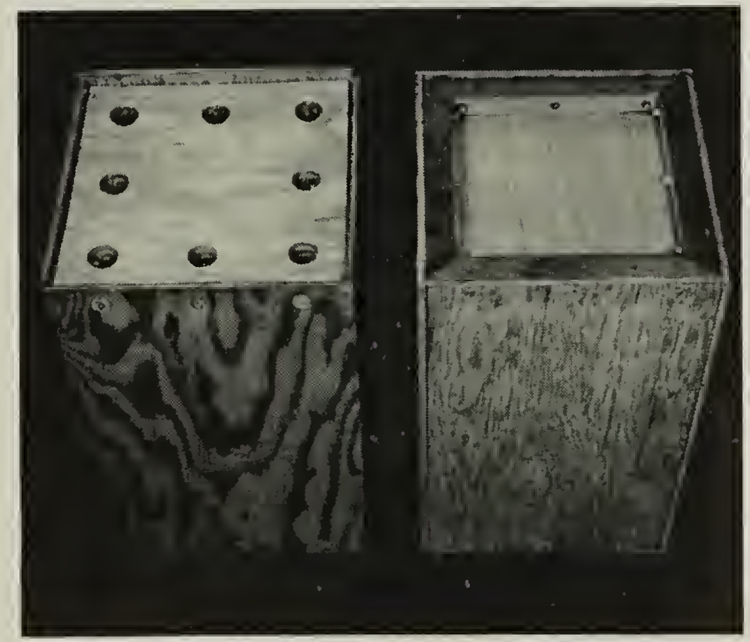


Ammunition box undergoing diagonal crushing test in standard testing machine. Inset shows step joint construction used in this box.

$3/8''$ plywood are even stronger, but the added strength might not be necessary for some uses.

A comparison of boxes of similar construction shows, as in previous tests, that the strength of plywood boxes having glued joints was greater than those with joints nailed only.

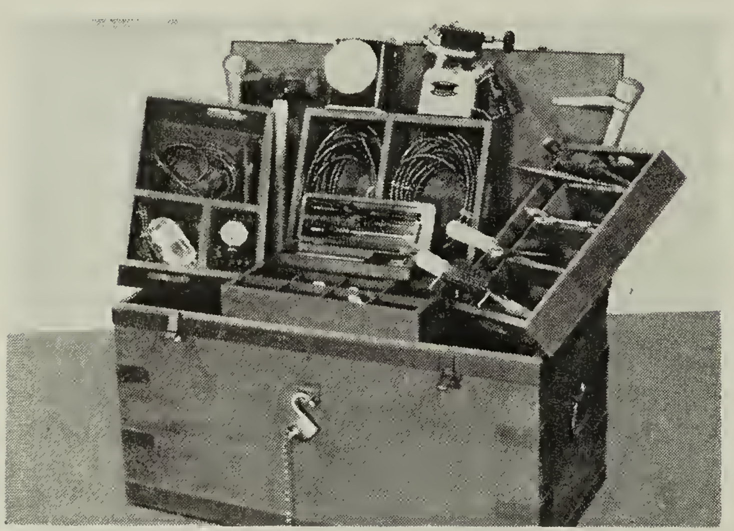
In boxes of this small size further use of plywood, as in the sides and ends, would not result in a further volume reduction, because it is inadvisable to nail into the edge of thin plywood; therefore, nailing cleats would have to be used. Also, the small size of the box permitted the use of one-piece lumber sides and ends with no edge-gluing required. In boxes of larger size the structural advantages of plywood construction would have been even more apparent.



Completely demountable plywood boxes which utilize tapered pins and collets for joint connections.

BOXES THAT CAN "TAKE IT"

Army Air Forces use nesting plywood boxes.



Signal Corps telephone maintenance chest is plywood.

Actual experience with boxes and crates of Douglas fir plywood bears out the favorable testimony of the laboratory testing as reported in the previous pages. The strength and rigidity of the panels, their lightness, their workability, the ease with which they can be glued, nailed or screwed, all these factors combine to make plywood a preferred packaging and crating material.

On this and succeeding pages will be shown a number of examples of the use of the engineered wood product to solve shipping problems. Many of the examples are of direct war uses, since they point up dramatically specific advantages, e.g., the Army Air Corps boxes and crates for safe packaging of expensive equipment and instruments, with a minimum of weight for transportation by air. The nesting boxes on this page are typical of this use.

Millions of square feet of Douglas fir plywood went into the manufacture of foot lockers, ordered by the Quartermaster Corps. Since every U. S. soldier is issued one of these foot lockers, the total constructed ran into the millions. At the right are

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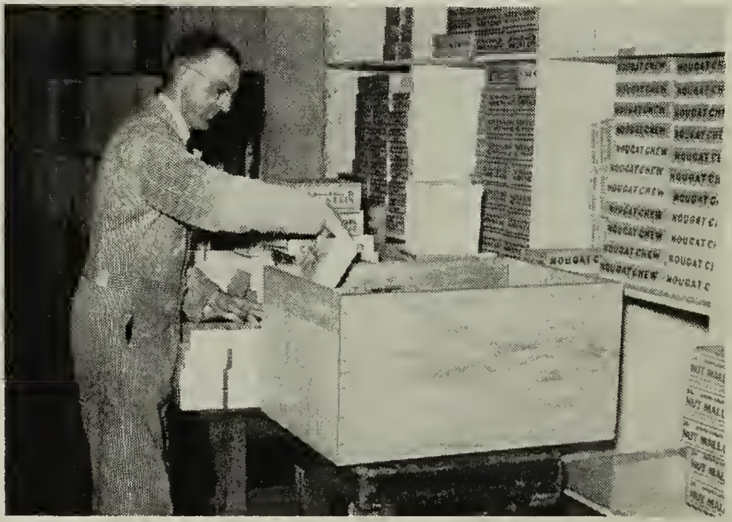
Air Forces nesting cases designed at Wright Field. Signal Corps telephone chest built by Hipewell Manufacturing Co., Yonkers, N. Y. Shipping cases at bottom used by (left) Jantzen Knitting Mills, Portland, Ore., and Brown & Haley Candy Co., Tacoma, Wash.

Jantzen swim-suits are packed in plywood crates.

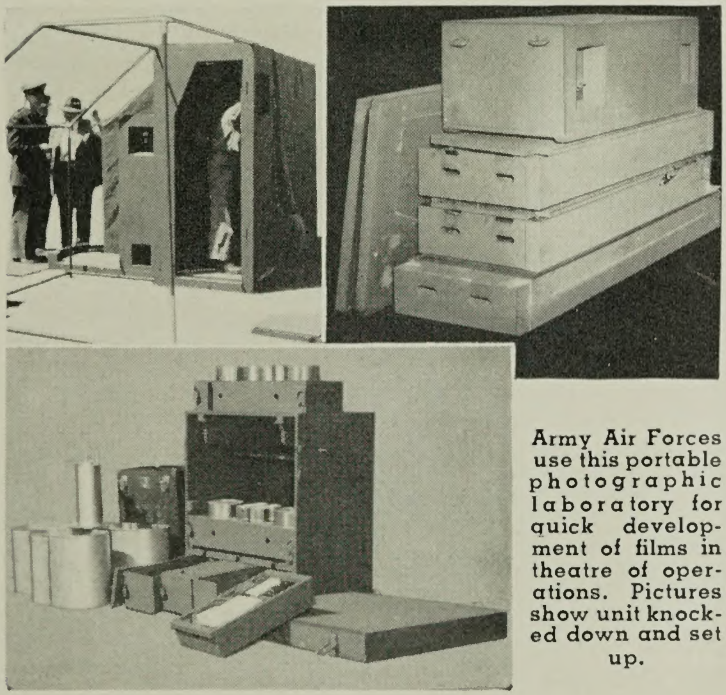


Candy stores receive their supplies in plywood boxes.

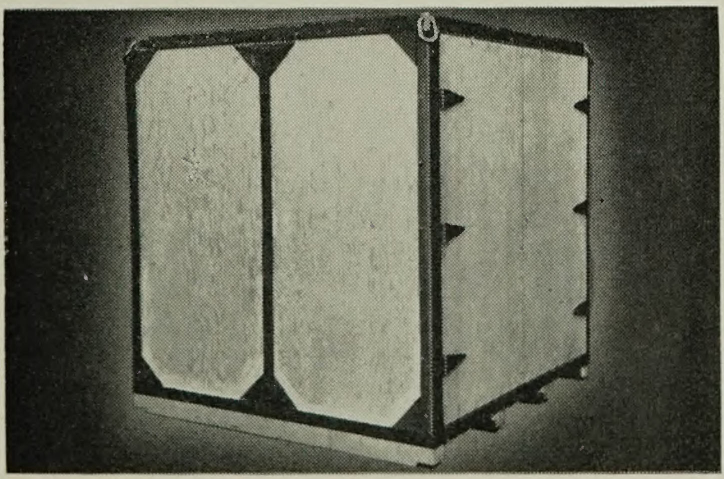
shown several steps in the manufacturing of this important supply item, illustrating the ready workability of the basic material, plywood.

The three photographs below illustrate another Air Force packaging problem which plywood assisted in solving. The unit is a portable photographic laboratory and it was designed to replace bulkier units which could not be moved by plane.

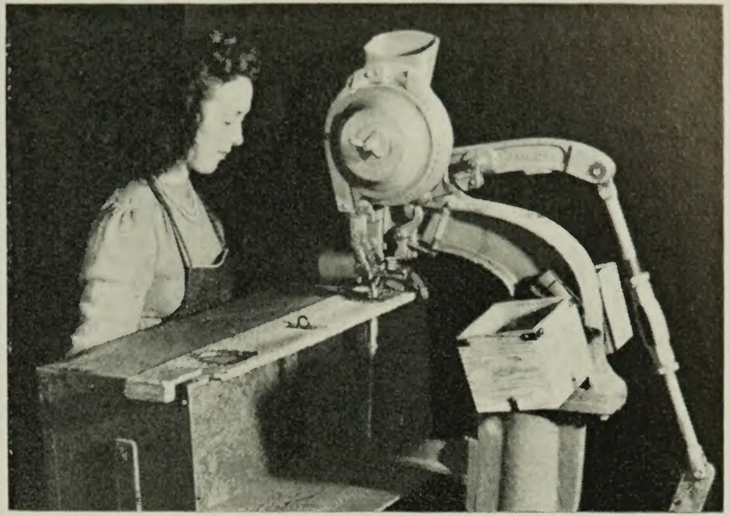
Caswell-Runyan Co., Huntington, Ind., builder of Air Forces portable laboratory developed at Wright Field. Seattle Luggage Corpn., Seattle, Wash., makers of foot locker and Signal Corps equipment chest, plywood mail box, Army Transport Service, Seattle, Wash.



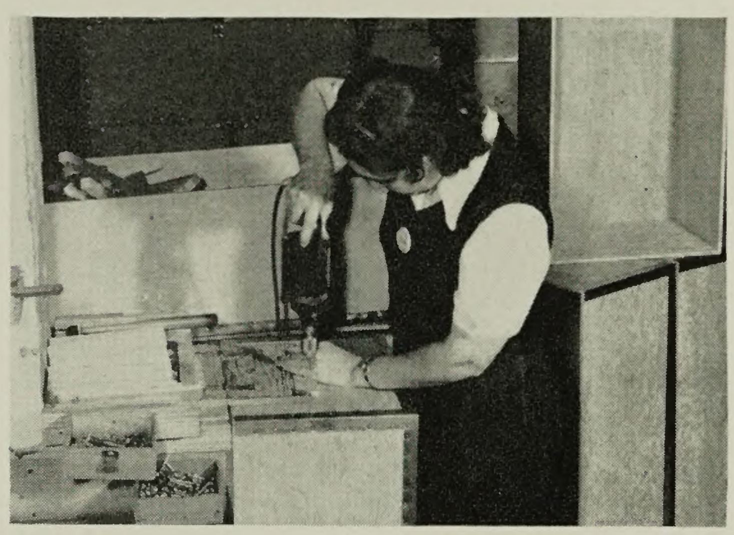
Army Air Forces use this portable photographic laboratory for quick development of films in theatre of operations. Pictures show unit knocked down and set up.



Sea-going plywood mail box holds 55 mail sacks.



Jig for drilling hinges for soldiers' foot lockers.



Foot lockers are mass produced with precision tools.

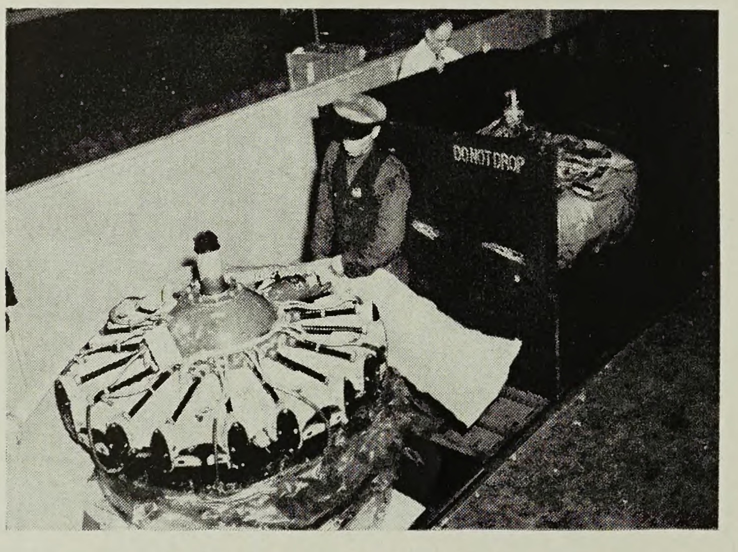
Completed locker is sturdy plywood construction.

Each U. S. soldier is equipped with a foot locker.

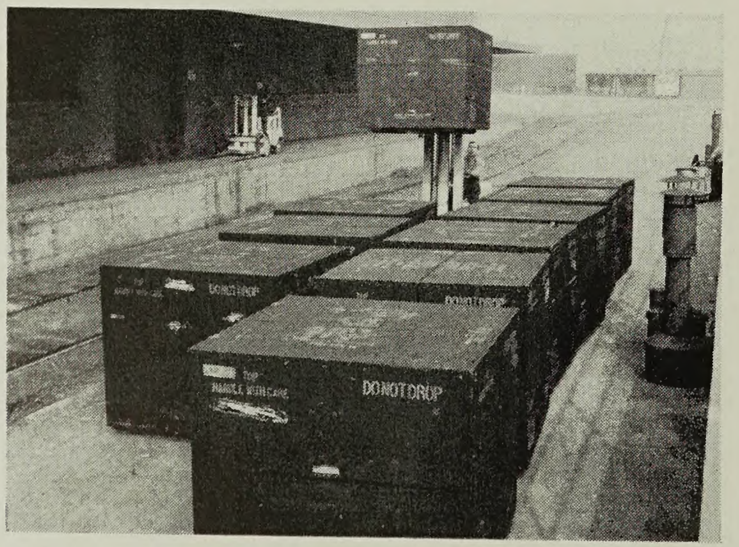
MOTOR CRATES

Airplane engines, both liquid-cooled and air-cooled types, are protected from damage during transit by precisely-built Douglas fir plywood crates. Most of these crates are demountable, and all may be used and re-used time and time again, prime factors in the selection of plywood as the basic material.

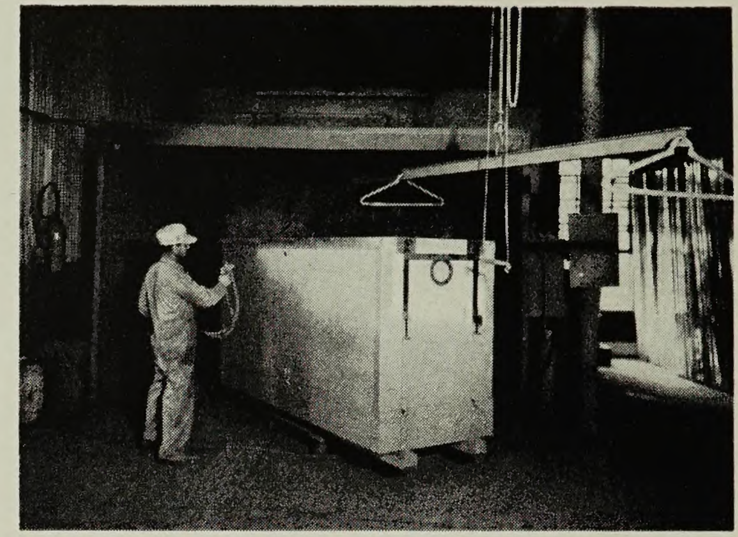
Re-uses of forty times have already been reported on the Allison crate, manufactured by the Indianapolis Wirebound Box Company.



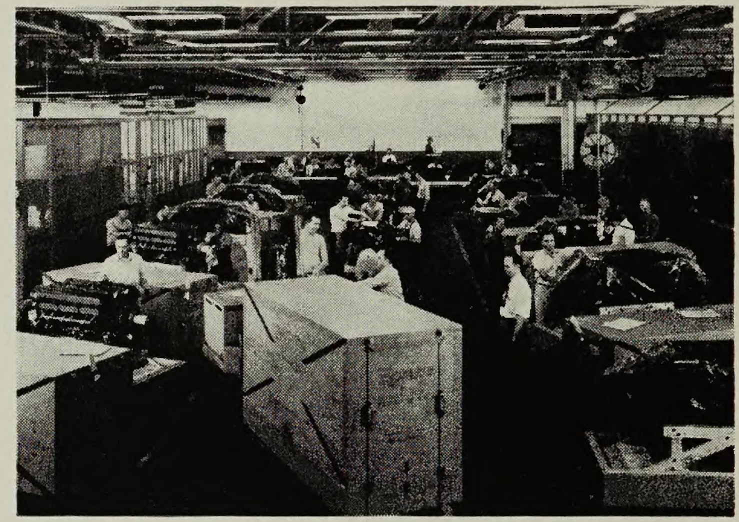
Engines of Boeing Flying Fortresses in plywood crates.



Crates are used and re-used; are easy to handle.



Allison motor crate of plywood receiving paint finish.



Packard-built airplane motors are also plywood-crated.

The large panels give the boxes great rigidity, at the same time reducing the weight and cubic capacity as compared with ordinary lumber boxes previously used. On the plywood box designed for radial motors and built by the Weiman Company of Rockford, Illinois, the weight is 405 lbs. as compared with 755 lbs. for the lumber box; the plywood box occupies 14½ cu. ft. less space; the original cost is less and it is completely demountable and re-usable, whereas only the cradle of the lumber box is salvaged for re-use.

Crates for radial engines built by The Weiman Co., Rockford, Ill. Indianapolis Wire Bound Box Co., Indianapolis, Ind., makers of boxes for Allison engines (built by Packard Aircraft Engine Division, Detroit). Page 15: Porto-van repair shops used by Air Forces, built by Herman Body Co., St. Louis, Fruehauf Trailer Co., Detroit and E. H. Sheldon & Co., Muskegon, Michigan. Photo of unloading transport by Signal Corps. Photos of airplane wing crate and boxes by Sacramento Air Service Command. South Bend Wood Parts Co., South Bend, Ind., builders of assembly boxes. Photo of shaft cases taken at Vancouver Shipbuilding Co., Vancouver, Washington.

AVERY
CLASSICS

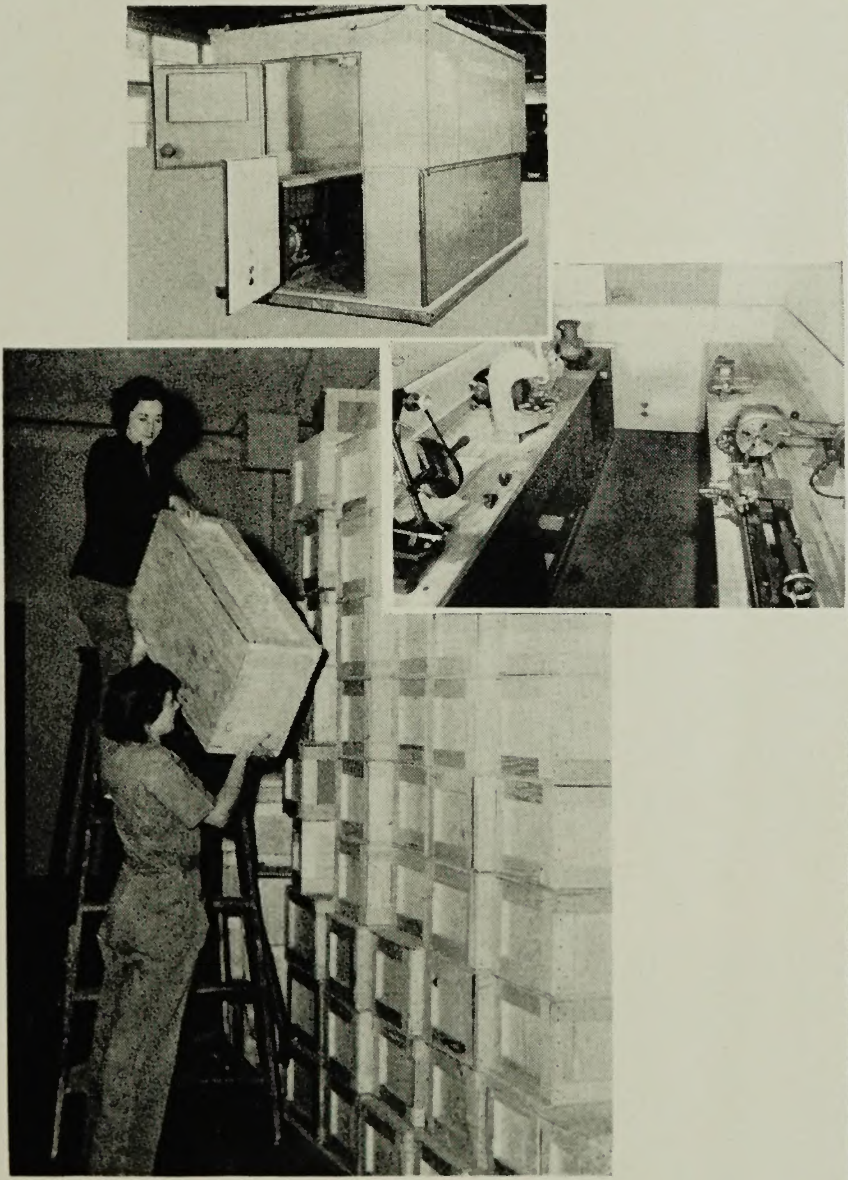
BOXES THAT GO TO WAR

Pictures on this page illustrate other wartime crating and boxing jobs that Douglas fir plywood is being called upon to do.

The picture directly below is a porto-van, or mobile field repair shop. Bodies of these vans split horizontally with top dropping over lower half to be moved easily about on small standard truck chassis.

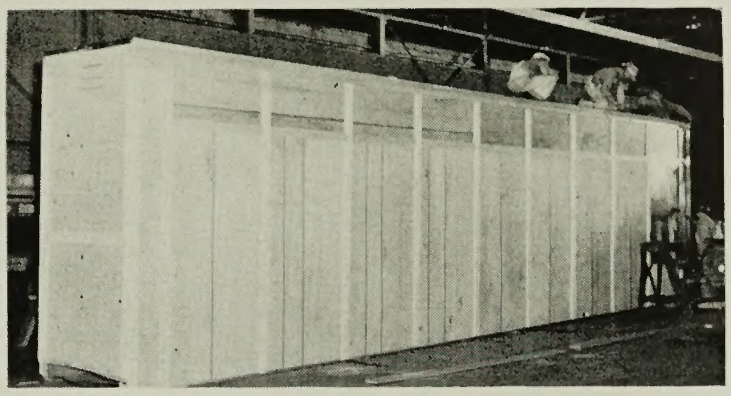
In moving materials to actual war theaters, particularly in landing operations, the tightness of plywood-constructed boxes, as well as strength and lightness in weight, dictates their use for much of the heavy, expensive cargo.

Porto-van for air forces repair shop that can be flown to advance bases.

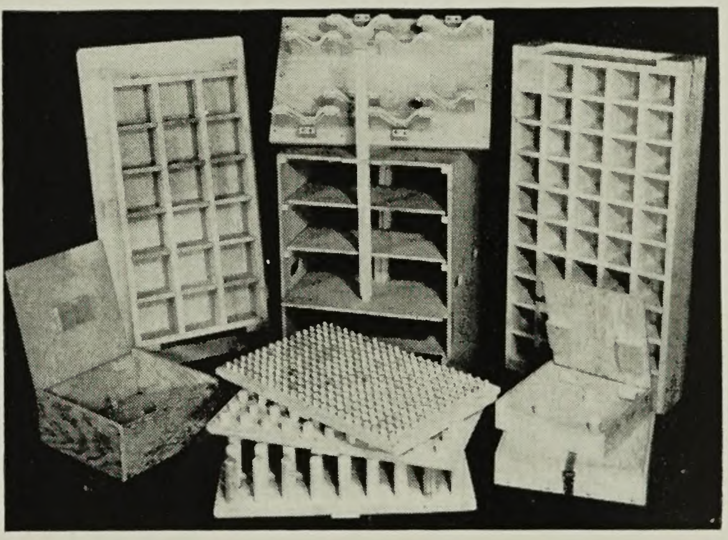


Standard plywood boxes used at army air base for spare parts.

Tight, light plywood boxes protect supplies in landing operations.



Plywood crate for airplane wing built at air-field.



Assembly boxes of plywood used in shipping airplane parts.

Propeller shafts for Liberty ships protected by plywood.

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